

Sea Ice

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Highlights

- The September 2013 Arctic sea ice minimum extent was 5.10 million km². This was 1.69 million km² greater than the record minimum set in 2012, but was still the sixth smallest ice extent of the satellite record (1979-2013).
- The amount of first year sea ice continues to increase, accounting for 78% of the ice cover in March 2013.
- A satellite-derived, Arctic Ocean-wide decrease in sea ice freeboard, from 0.23 m in March 2011 to 0.19 m in March 2013, implies a 0.32 m decrease in ice thickness, from 2.26 m to 1.94 m.



Sea Ice Extent

Sea ice extent is used as the basic description of the state of the Arctic sea ice cover. Satellite-based passive microwave instruments have been used to determine sea ice extent since 1979. There are two months each year that are of particular interest: September, at the end of summer, when the sea ice reaches its annual minimum extent, and March, at the end of winter, when the ice is at its maximum extent. The sea ice extent in March 2013 and September 2013 are presented in **Fig. 19**.

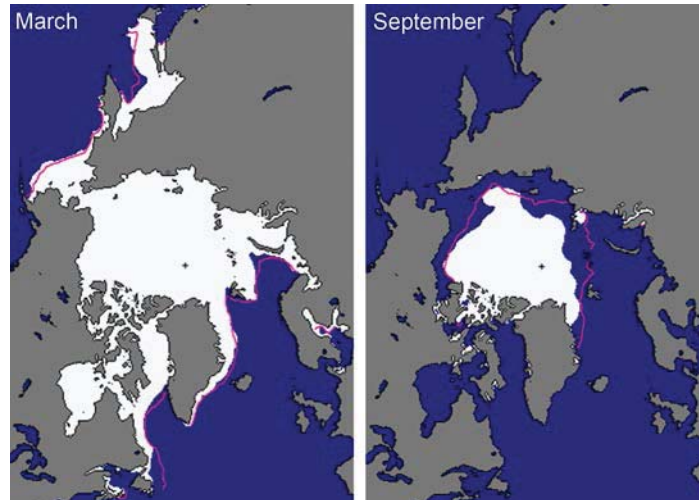


Fig. 19. Sea ice extent in March 2013 (left) and September 2013 (right), illustrating the respective monthly averages during the winter maximum and summer minimum extents. The magenta lines indicate the median ice extents in March and September, respectively, during the period 1981-2010. Note that the median ice extents are computed over a different time interval than the one (1979-2000) used in previous Arctic Report Cards, as explained by NSIDC at http://nsidc.org/data/seaice_index/baseline-change.html. Maps are from NSIDC at nsidc.org/data/seaice_index.

Based on estimates produced by the National Snow and Ice Data Center (NSIDC) the sea ice cover reached a minimum annual extent of 5.10 million km² on September 13, 2013. This was substantially higher (1.69 million km²) than the record minimum of 3.41 million km² set in 2012 (**Fig. 20**), making it the largest September minimum ice extent since 2006. However, the 2013 summer minimum extent was still 1.12 million km² below the 1981-2010 average minimum ice extent. In March 2013 ice extent reached a maximum value of 15.04 million km² (**Fig. 20**), 3% below the 1981-2010 average. This was slightly less than the March 2012 value, but was typical of the past decade.

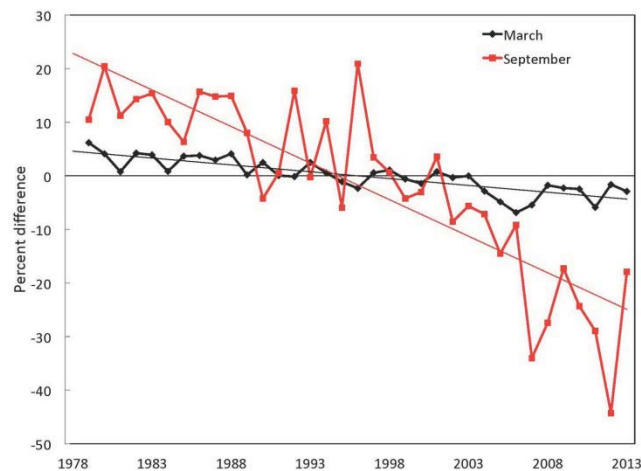


Fig. 20. Time series of ice extent anomalies in March (the month of maximum ice extent) and September (the month of minimum ice extent). The anomaly value for each year is the difference (in %) in ice extent relative to the mean values for the period 1981-2010. The black and red lines are least squares linear regression lines. The slopes of these lines indicate ice losses of -2.6% and -13.7% per decade in March and September, respectively.

Sea ice extent has decreasing trends in all months and virtually all regions (the exception being the Bering Sea during winter). As of 2013, the September monthly average trend is -13.7% per decade relative to the 1981-2010 average (**Fig. 20**). This is slightly lower than the trend (-14% per decade relative to the 1981-2010 average) in 2012, which was the twelfth consecutive year of progressively larger trends of summer ice retreat. Trends are smaller during March (-2.4% per decade, **Fig. 20**), but are still decreasing and statistically significant.

There was a loss of 9.69 million km² of sea ice between the March and September extents. This is the smallest seasonal decline since 2006. After reaching the March maximum extent, the seasonal decline began at a rate comparable to the 30-year average (not shown). Through the end of June the 2013 ice extent was just slightly less than the 30-year average values. For a few weeks in late-June and early-July the decrease in ice extent was greater than average. Subsequently, the 2013 ice extent tracked the shape of the average ice extent curve for the remainder of the summer melt season, but at a value about one million km² less than the average curve.

Age of The Ice

The age of the sea ice is another key descriptor of the state of the sea ice cover. The age of the ice is an indicator for its physical properties including surface roughness, melt pond coverage, and ice thickness. Older ice tends to be thicker and thus more resilient to changes in atmospheric and oceanic forcing than younger ice. The age of the ice can be determined using satellite observations and drifting buoy records to track ice parcels over several years (Tschudi et al. 2010). This method has been used to provide a record of ice age since the early 1980s (**Fig. 21**). The distribution of ice of different ages illustrates the extensive loss in recent years of the older ice types (Maslanik et al. 2011).

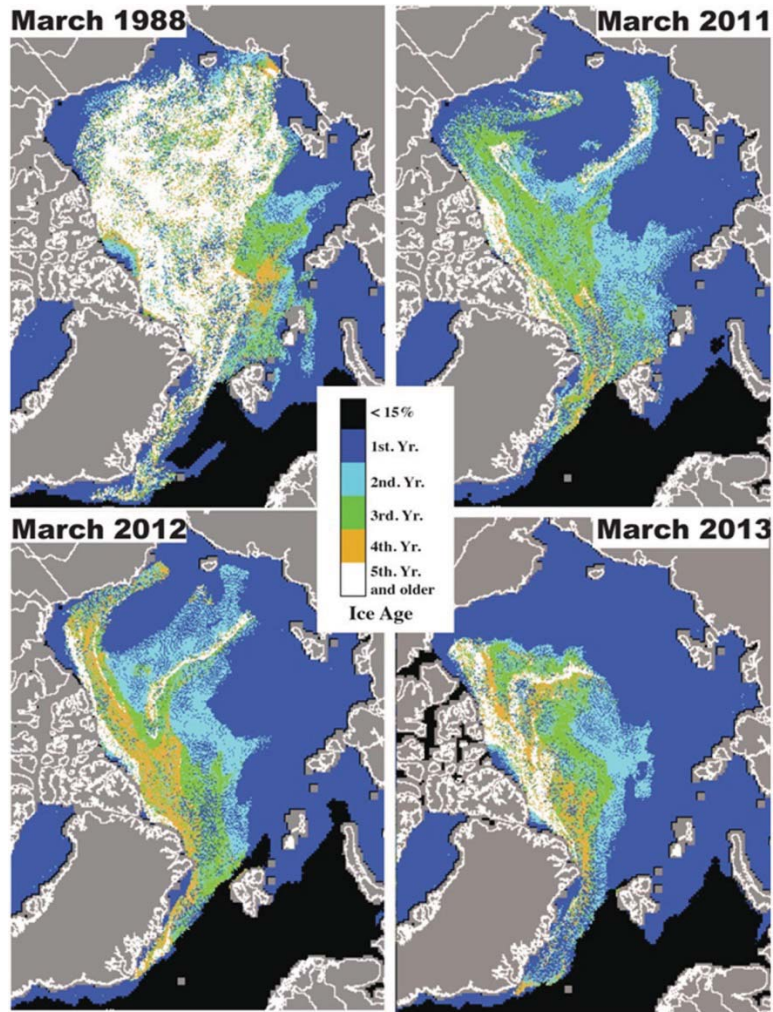


Fig. 21. Sea ice age in March 1988, 2011, 2012 and 2013, determined using satellite observations and drifting buoy records to track the movement of ice floes.

Although the minimum sea ice extent rebounded somewhat in 2013, the distribution of ice age continued to favor first-year ice (FYI, ice that has not survived a melt season), which is the thinnest ice type (e.g., Maslanik et al. 2007). In March 2013, FYI comprised 78% of the ice, up slightly from 75% in 2012. In March 1988, 58% of the ice pack was composed of first-year ice. Meanwhile, the trends continue for the recent loss of the oldest ice types, which accelerated starting in 2005 (Maslanik et al. 2011). For the month of March, the oldest ice (4 years and older) has decreased from 26% of the ice cover in 1988 to 19% in 2005 and to 7% in 2013.

At the end of winter 2013 little multiyear ice was detected in much of the Beaufort Sea (**Fig. 21**, lower right; and Richter-Menge and Farrell 2013). There is no precedent in the satellite-derived record of ice age for the near-absence of old ice in this region, which appears to have been due to a combination of the previous year's record sea ice retreat and a lack of subsequent transport of multiyear ice into the Beaufort Sea during winter 2012-2013. Negligible multiyear ice transport into the Beaufort Sea continued during summer 2013. Nor did multiyear ice drift into Siberian Arctic waters, which is also very rare. Multiyear ice remained confined to the region north of Greenland and northernmost Canada during 2013.

Ice Thickness

The key state variable for the Arctic sea ice cover is ice thickness. In recent years, ice thickness has been estimated over limited regions by aircraft, e.g., the NASA Operation IceBridge (Richter-Menge and Farrell 2013), and over large regions by satellite. The CryoSat-2 satellite, operated since 2011 by the European Space Agency, measures ice freeboard, the height of ice floes above the water line. Preliminary analysis indicates that the Cryosat-2 freeboard estimates are comparable to *in situ* field measurements, with a level of uncertainty that is comparable to other airborne and satellite-based observations. A more detailed error analysis of the freeboard estimates is currently in progress. Calculation of the actual sea-ice thickness from freeboard requires knowledge of snow depth, but in general higher freeboard indicates thicker sea ice. Therefore, freeboard maps in spring in the period from 2011 to 2013 are a proxy for sea ice thickness at the time of maximum ice extent (**Fig. 22**). During the three years of observation by Cryosat-2, the average freeboard has decreased by 0.04 m, from 0.23 m in 2011 to 0.19 m in 2013 (Laxon et al. 2013). Assuming no significant change in snow depth, the decline in freeboard amounts to a mean sea ice thinning of 0.32 m, from 2.26 m in 2011 to 1.94 m in 2013. As with the ice age maps (**Fig. 21**), the Cryosat-2 freeboard maps indicate that most of the thickest and oldest ice occurs to the north of Greenland and northernmost Canada, and it is a small proportion of the total sea ice cover at the end of winter (**Fig. 22**).

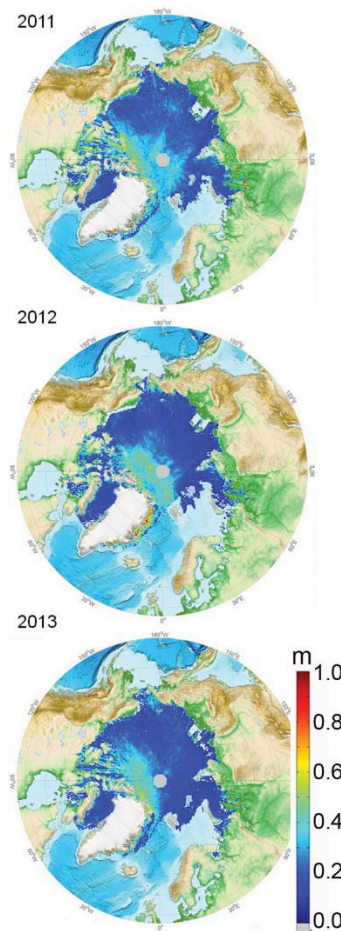


Fig. 22. Ice freeboard (in meters) estimates from Cryosat-2 in March 2011, 2012 and 2013.

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